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Exact model of Langevin transducers with internal losses

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An exact method is presented to analyze classical Langevin transducers with internal losses. The transducers consist of an axially polarized piezoelectric cylinder sandwiched between two elastic cylinders. All three cylinders are of the same diameter. Exact solutions to the exact equations of motion of the piezoelectric and elastic cylinders and the Gauss electrostatic condition are used. Complex piezoelectric and elastic coefficients are used to model internal losses. For each cylinder, the first set of solutions contains Bessel functions that form a complete set in the radial direction. The second and third sets contain trigonometric functions that form complete sets in the axial direction. They are used to represent fields that are symmetric and anti-symmetric with respect to the plane midway between the ends of the cylinder, respectively. The interface and boundary conditions are satisfied by using the orthogonal properties of the functions. Transducers with identical elastic cylinders at the ends as well as those with a light head mass and a heavy tail mass are analyzed. Numerical results are presented to illustrate the input electrical admittances of transducers. They are compared with those obtained using ATILA - a finite element package for the analysis of sonar transducers.